UNCLASSIFIED

AD NUMBER
AD253588
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; FEB 1961. Other requests shall be referred to Office of the Under Secretary of Defense, Washington, DC 20301.**
AUTHORITY
ousd, 2 feb 1993

THIS PAGE IS UNCLASSIFIED

UNCLASSIFIED

AD 253 588

Reproduced
by the

ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA

UNCLASSIFIED

AD No. 253588
ASTIA FILE COPY

GRAVITATIONAL CONTROL RESEARCH

John T. Watson 817600

61-2-6 NOX

FILE COPY
Return to
ASTIA
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA
•
Attn: TISSS

ASTIA
RECEIVED
APR 6 1961
TIPDR

GRAVITATIONAL CONTROL RESEARCH

GRAVITATIONAL CONTROL RESEARCH

A Report Presented to the Faculty of the Graduate School

of

Southern Methodist University

in

Partial Fulfillment of the Requirements

for the Degree of

Master of Science

in

Electrical Engineering

by

John T. Watson
(B.S. in E.E., Southern Methodist University, 1954)

February, 1961

PREFACE

All presently known propulsion systems apply a localized force to a rigid body. In contrast, the forces resisting motion (weight and inertia) are acting upon each constituent particle of the body--thereby limiting the acceleration to which it may be subjected. This limit depends upon the strength of the molecular bonds within the materials which compose the body, and these bonds will fail when a differential force applied across them is too large. Such a differential force can arise when an excessive propulsive force is applied against the inertia and/or weight of the more isolated members of the body. The strength of the molecular bond, then, determines the maximum acceleration of the body. Acceleration limits on present vehicles are a few multiples of gravity (g's).

If propulsive force could be applied at the fundamental (probably subnuclear particle) level of matter, the limitations just mentioned would no longer be valid. The concept of "gravitational control" to be discussed in this report will be concerned with the modification of forces (gravitational and inertial) at this level.

Several authors who have published articles of a popular nature on the control of gravitation during the past

few years have not been bound by this definition of gravitational control. As a result, some of their statements about gravitational control (or "anti-gravity", a term acquired from the authors of science fiction) encompass a wide spectrum of theories ranging from those which may be applicable to those which are unrelated to gravitational control. A few of these articles actually do an injustice to the serious research which is being conducted relative to gravitational control either by presenting misconceptions or misinterpretations of the facts concerning the status of this research. Misconceptions have even allowed the inclusion of such proposals as ion and photon propulsive devices within the category of gravitational control. While this is an extreme case, there are other schemes which have been erroneously included in this category. The "electro-gravitics" concept of Townsend Brown is such a scheme.

Mr. Brown has received a moderate amount of publicity concerning his scheme for gravitational control.(1)(2)(3)(4)(5)* In the 1920's he conceived the possibility of constructing a device which would utilize the reaction between electrostatic and electromagnetic fields for the purposes of levitation and propulsion. Since he felt that his device was also utilizing an interaction between electromagnetic and gravitational fields, he referred to this principle as

---

* Numbers in parentheses refer to articles in the Bibliography.

"electro-gravitics". Within the past ten years, a model of this device has been demonstrated and Mr. Brown feels that if he can improve the charge capactiy of his model, it will operate with Mach 3 capability within the earth's electromagnetic field. Originally, Mr. Brown had attributed antigravity properties to his vehicle. Now it would appear that it is no more than a rather sophisticated utilization of known effects. Since it does not modify forces at the fundamental level of matter, the "electro-gravitics" device of Mr. Brown is not within the realm of the gravitational control concept which is to be discussed in this report.

Some of the advantages of force application at the fundamental level of matter have been pointed out in articles by A. R. Weyl and others.(6)(7)(8) From their analyses, it seems that a major advantage in the construction of a vehicle capable of generating a field which could provide a force at the particle level is that it would have it's own gravitational field. Then, since each particle within the vehicle's field would be acted upon simultaneously, the occupants of such a vehicle could withstand unlimited accelerations. Also, with the sustained accelerations possible in such a vehicle, it's speed outside of the earth's atmosphere could approach that of light. Inside the atmosphere, the effects of air resistance would impose some limitations, but the speed and maneuverability would be far beyond that of any other vehicle conceivable by cur-

rent standards.

All presently known forms of mass are subject to the attractive force of gravity.(8) Since this applies to the subnuclear particles, it is reasonable to assume that the achievement of gravitational control will probably result from either 1) a neutralization of the gravitational field at the particle level, or 2) forces applied at the particle level to overcome gravitational and inertial effects.

Success in attaining control over gravitation seems unquestionably tied to a better understanding of gravitation. At the present time, most of the work being done towards gaining gravitational control is centered around the quest for better knowledge concerning the nature of gravitation. This report will be concerned with some of the more applicable theories and research. The information ~~will be~~ discussed in four sections: Introduction, Characteristics of Gravitation, Theories of Gravitation, and Current Research Effort. Some of the material will, of necessity, fall into more than one category.

Most of the current theories on gravitation are subject to question by one or more theorists in the field. It is difficult to resolve the differences of opinion in almost all phases of theory and even in the establishment of the less controversial characteristics of gravitation. These questions will be noted in all cases where it is felt that there is justifiable doubt.

Underlying most of the difficulty, and opening wide the door to controversy, is the lack of information as to the true nature of gravitation. Further complicating the problem is the extreme difficulty of carrying out experimental work. While on an astronomical scale the interactions between masses are quite large and can be measured with fair accuracy, the magnitude of gravitational interaction between masses on the subatomic level is so small as to be considered quite negligible in comparison to other intra-nuclear forces. This makes the detection of gravitational effects on this level virtually impossible.

TABLE OF CONTENTS

INTRODUCTION

The first historical evidence of man's thoughts concerning the effects of gravitation are attributed to the Greek philosopher, Aristotle, around 350 B.C.. He classified all matter by it's "natural" habitat. The tendency of heavy objects to gravitate associated them with the earth. The tendency of light objects (smoke, fire, and air) to levitate associated them with the sun, or sky. This thinking remained until the time of Galileo (1564-1642).

After Galileo demonstrated the independence of gravitational acceleration from mass, various theories were proposed to account for this effect. The most prevalent was the vortex theory advanced by the French mathematician and philosopher, Rene Descartes (1596-1650). He theorized that the universe was made up of a series of vortices, all limiting and circumscribing each other. This theory persisted even after the advent of Kepler, who showed that the orbits of the planets were constrained to be ellipses, and Newton, whose laws of motion and universal gravitation demonstrated that the vortex theory could not be valid.

Newton, however, proposed no theory concerning the nature of gravity. In fact, he made the statement in the second and third editions of the Principia, "Hitherto I

have not been able to discover the cause of these properties of gravity from phenomena, and I frame no hypothesis".

After Newton, several theories were advanced. In these theories, attempts were made to account for gravity by stresses in the ether, corpuscular action, electric attraction and repulsion, electrodynamic waves interacting with matter, etc..

The concept of action-at-a-distance, which was a basic requirement for gravity in Newton's theory, was almost completely unacceptable in the minds of physicists in later years. Even Newton himself could not accept it completely. Nevertheless the mathematical relationships which he had developed seemed to require that this be true.

The conceptual problem was rectified when Einstein developed his general theory of relativity. He used Minkowski's concept of the space-time continuum to show that the effects of gravitation are associated with a field. Thus the gravitational field replaced the old requirement for action-at-a-distance.

Einstein relativity opened up new vistas in the scientific world. The gravitational field of the general theory explained the anomoly in the orbit of the planet Mercury, as well as predicting two new effects which have subsequently been verified. These effects were: 1) the deflection of light passing through a strong gravitational field (verified by noting that the light from stars appear-

ing in the vicinity of the sun was deflected), and 2) the spectral red shift due to the shift in wavelength of light emitted by atoms in a gravitational field (the wavelength of light from the very dense white dwarf, the companion to Sirius, is much longer than that encountered on the earth). This experimental verification of some of Einstein's principles gave credence to the remainder.

The general theory of relativity provided a new theory of gravitation, but electromagnetic concepts have remained apart from the theory. To correct this failing, unified field theories would group the electromagnetic and gravitational fields together as a part of the geometrical structure of space. Some of these unified field theories will be discussed later in the report.

Another failing of the general theory of relativity is that, due to the nature of it's mathematical basis, it does not provide a satisfactory theory of matter. The elementary particles found within nature have individual characteristics which set them apart from each other. These characteristics are mass, charge, etc.. Within the theory of relativity, these particles are merely singularities of the field equations. This cannot explain why these particles exhibit individual characteristics. Again, it is felt that a unified field theory should be able to provide an explanation.

The quantum theory was developed almost colaterally

with the general theory of relativity. Quantum mechanics sought to provide rules for the interaction of microscopic particles. This theory found application in regions where the general theory of relativity did not apply. The prediction and discovery of new subnuclear particles resulted from applications of the quantum theory to electrodynamics. Presently, it is believed that quantum electrodynamics gives an exact picture of all physical phenomena other than those which involve nuclear forces, gravitation, or the weak interactions.(9)

The restrictions placed upon the present realms of applicability of both the quantum theory and the general theory of relativity are such that the quantum theory is valid only for microscopic regions (radii of the order of 10^{-8}cm), and the general theory of relativity is valid only within macroscopic domains. There are postulates which would link one or more aspects of these theories with others, but there is nothing which contributes to the ultimate unification of the realms of both.(10)

There is almost nothing in gravitational knowledge which is not questioned either by theorists or by the people who are doing experimental work. The interpretation of the more commonly accepted measurements associated with gravitational fields is no exception.

CHARACTERISTICS OF GRAVITATION

A. Equivalence: Gravitational and inertial mass of the same body are always equal. This follows from Galileo's famous experiment in which he showed that the acceleration of a body in a gravitational field is independent of it's mass. The most accurate determination of this equality was made in 1922 by Eötvös.(11) Using his torsion balance, he found that there was no deviation up to six parts in one billion between the gravitational masses of a wide variety of materials which included substances before and after chemical reaction as well as radioactive materials.

B. Isotropy: The anisotropic properties of some crystals with regard to heat, electricity, and light are well known. The possibility that crystalline structure might exhibit anisotropic properties with respect to gravity was investigated by Paul R. Heyl at the National Bureau of Standards in 1924.(11) Crystals, while oriented in various ways with respect to the earth, were weighed. No deviation of as much as one part in one billion was discovered. Experimentation with steel in magnetized and unmagnetized states also provided negative results.

C. Temperature: In 1922, P. E. Shaw conducted experiments which revealed the independence of gravitation

from temperature effects to two parts in one million per degree centigrade.(11) Astronomical evidence verifies this to an even greater degree of accuracy. Comets which approach close to the sun in their orbits are heated to a very high temperature. If temperature had affected gravitation, their orbits would be altered considerably. Over a period of many years there have been no unexplainable variations in the orbits of the comets.

Effects at the other end of the temperature scale have also been investigated. No gravitational anomolies have been noted down to the immediate region of absolute zero.

D. Inverse Square Law: The relationship developed by Newton that the force of attraction between two bodies is proportional to the inverse square of the distance separating them is verified by the observation of astronomical bodies.

The only question raised as to the validity of this relation was by Leverrier in 1845. He noticed an irregularity between the actual path of the planet Mercury and that predicted through the use of the inverse square relationship. This anomoly was noted by others and an attempt was made to verify it using Newton's laws. This was unsuccessful. The irregularity was to be explained, finally, by Einstein's general theory of relativity in 1916.

One attempt to explain this discrepancy was made by

Asaph Hall of the U. S. Naval Observatory. He proposed to use 2.0000001612 for the power to which the distance separating the bodies is raised. This would have accounted for the orbit's unexplained precession. E. W. Brown pointed out that the motion of the earth's moon would not allow the slightest deviation from the power of 2.(11)

E. Interactions: Of all of the known interactions, that which is due to gravitation is the weakest. While on an astronomical scale gravitational force seems large (in order to keep the earth in it's orbit a force of 2×10^{18} tons is exerted upon it), the same relation between subatomic particles is quite small (the gravitational force between the proton and the electron is 5×10^{-40} times that of the electrostatic interaction).(12)

F. Permeability: There is no known shielding for the gravitational field. This is in contrast to the effects of the electromagnetic field in which many substances are found to be opaque. There are also those substances which have this characteristic with respect to heat and sound.

The best evidence of the absence of this phenomena in gravitation is, again, astronomical. If there were any shielding of the sun's gravitational field by the earth, for instance, the moon would recede slightly every time it is eclipsed. It would not take many eclipses for this recession to be noticeable.

G. Universality: All forms of mass are affected re-

gardless of size. The elementary particles of nuclear physics, even the newer so-called anti-matter particles, are subject to gravitational attraction.(8) This includes the photon which has mass due only to it's speed (inertial mass).

Since it appears that gravitational forces are quite negligible in comparison to the other forces binding atoms together, it is possible that slight variations in the gravitational interactions at the atomic level could have gone unnoticed despite the high degree of accuracy with which some of the measurements have been made.

THEORIES OF GRAVITATION

Most phenomena occuring throughout the universe may be attributed to gravitational and/or electromagnetic effects upon matter. On a cosmological level, the interactions between masses may be completely explained as gravitational. Within the constituent parts of matter (molecules, atoms), the interactions are predominantly electromagnetic in nature down to the subnuclear domain.

The identity of the binding forces within the nucleus is still in doubt; however, it is generally believed that these forces are essentially non-electromagnetic. Yukawa has introduced the concept of the meson field in order to account for the nuclear binding forces.(9) Much more is to be learned about phenomena at this level, however.

The physicists' search for an answer to unexplained phenomena has led to theories which attempt to explain observations. The discrepancy encountered in the Michelson-Morley experiment stimulated the thinking of Albert Einstein. This led to the special theory of relativity, and ultimately, to the general theory of relativity. The desire to find an answer to radiation problems stimulated the thinking of Max Planck. This led to the development of the quantum theory.

Both theories have made contributions leading to a better understanding of the fundamental structure of the universe, although the general theory has been restricted to the macrocosm, and the quantum theory has been restricted to the microcosm. In the scientist's search for the fundamental secrets of matter, it seems that a link between the two theories is required. Much of the current theoretical efforts are aimed in this direction.

Einstein's general theory of relativity is based upon the validity of the principle of equivalence. This principle equates a gravitational field and a uniform acceleration. This equivalence may best be understood by considering an analogy. Suppose there were an observer in a closed room who desires to verify this equivalence. Within this room he can observe no difference between the effects due to it's presence on the surface of the earth and those generated after removing it from the earth's gravitational field and continuously applying a force sufficient to give it a uniform acceleration of 32.2 feet per second^2. Thus, localized gravitational effects may be transformed into an accelerated frame of reference. This equivalence leads to the use of generalized frames of reference, and, ultimately to the appearance of the Riemannian form of the four dimensional Minkowski space-time continuum which allows the gravitational force to be transformed away.

Within the Riemannian space-time continuum the devel-

opment of the gravitational field becomes possible.(12) This continuum is distorted by the presence of matter. The geometry of the continuum determines unique paths for bodies moving within it. Consequently, gravitational acceleration is the result of motion through the distorted continuum in the vicinity of a mass.

The "easiest" connecting path between any two space-time points is called a "geodesic". In Riemannian space, the line element, ds, between two space-time points is given by the metric:

$$ds^2 = \sum_{\mu\nu} g_{\mu\nu}\, dx^\mu dx^\nu \quad ; \mu, \nu = 1,2,3,4 \qquad (1)$$

where: dx^μ, dx^ν = the differential coordinates of the space-time points (resulting from the expression of the interval, ds, in curvilinear coordinates).

$g_{\mu\nu}$ = elements of the metric tensor (dependent both upon the coordinates and the characteristics of the continuum).

The path of a particle between two space-time points is determined by applying the variational principle in such a way that it is a minimum.

$$\delta \int ds = 0 \qquad (2)$$

The line integral is taken along the path connecting the two points.

In the presence of a gravitational field, the

appearing in equation (1) become the gravitational potentials. This metric tensor is responsible for determining the gravitational field, in addition to being related to the curvature of the continuum.

The field equation for gravitation is given by:

$$R_{\mu\nu} - \tfrac{1}{2}R\, g_{\mu\nu} = -\frac{8\pi G}{c^4} T_{\mu\nu} \tag{3}$$

where: $R_{\mu\nu}$ = the second rank tensor contracted from the fourth rank tensor $R^{\sigma}_{\mu\nu\rho}$ (the Riemann-Christoffel tensor, which is a measure of the curvature of this space-time), with respect to ρ and σ.

R = the scalar resulting from further contraction of $R_{\mu\nu}$ with respect to μ and ν.

$T_{\mu\nu}$ = the energy-momentum tensor that describes the distribution of energy and matter which produces the distortions of the continuum.

G = the gravitational constant.

This equation results from the application of the variational principle:

$$\delta \int (L + R)\sqrt{-g}\; d^4x = 0$$

where L is the Langrangian density of the matter, and $\sqrt{-g}\; d^4x$ is an element of volume in space-time.

When equation (3) is solved for the case of a spherically symmetrical mass distribution, the resulting metric tensor used with equation (2) gives the equation for the path of the planet Mercury around the sun. This equation accounts for the previously noted irregularity. By similar use of the results of the equation (3), the deflection of light rays in gravitational fields, and the shift of wavelength of light emitted in a gravitational field were predicted.

There are other effects which have been predicted by the gravitational theory. Among them is the prediction of the wave character of gravity and the speed of it's propagation. The speed of propagation is predicted to be the same as that of light. Both of these characteristics are still subject to verification. Several of the experiments mentioned later seek to generate these predicted waves.

Although the quantum theory was introduced by Planck and Einstein in the early 1900's, it was not until after 1926 that the theory was used other than in those cases where classical mechanics failed to provide a reasonable solution to particular problems. In that year, working separately, Schroedinger and Heisenberg formulated the laws of quantum mechanics. This formulation made possible the unification of the principles of both the quantum theory and the laws of classical mechanics, insofar as the study of the microscopic domain is concerned.

In 1927, Dirac brought the principle of relativity into the laws of quantum mechanics. This enabled him to develop the principles of quantum electrodynamics. While this apparently gave the basis for the complete quantization of atomic particles, there were still some limitations.

In the attempt to explain the properties of the electron and the positron, the theory of quantum electrodynamics is found to be physically incomplete. It cannot explain the observed value of the dimensionless constant of coupling associated with the electron charge. Since this charge is a property of all of the fundamental particles with direct or indirect magnetic coupling, as well as of the electromagnetic field, a full understanding of the electron charge will have to wait for more information about the fundamental particles.(13)

There is a possibility that successful quantization of the gravitational field will help to clarify the difficulties which quantum electrodynamics encounters in the lower regions of atomic structure. Of course, this would give the long sought for unified field theory, as well. Much of the theoretical work which is being done in this country seems to be centered around this problem of quantization.

At the University of North Carolina, a group led by Dr. Bryce S. DeWitt and Dr. Cecile M. DeWitt is trying to determine the proper sequence of operations in the reduc-

tion of the quantized gravitational theory to a usable form. A group working with Professor P. G. Bergmann at the University of Syracuse is attempting to obtain an appropriate expression for the energy and for the associated quantities which are conserved in the transformation. The mathematical complexities of their tasks are almost insurmountable. These mathematical difficulties arise from the nonlinearity of the Einstein gravitational field equations. It is difficult enough to work with nonlinear equations; these, however, are complicated further through quantization.(14)

The particle resulting from the quantization of the gravitational field would be the graviton. The nonlinearity of the equations describing the field indicates that the gravitons would interact with each other rather than propagating in the free manner of the photons of the electromagnetic field. The reason for this is that the gravitational field is created not only by the stress in the continuum, but also by itself. The energy carried by the gravitational field is also instrumental in creating the field.

Certainly, with all of the difficulties associated with the quantization of the gravitational field, the question of the ultimate success of such endeavors arises. There is a possibility, voiced by Einstein and others, that the gravitational field is the one field which will never yield to the process of quantization; the gravitational

wave may be the only wave which does not have a particle associated with it.(14)

In later years, much of Einstein's efforts were devoted to the development of the unified field theory. In the 1930's, he felt that he had been successful in accomplishing this task and published his theory; later, due to an error in the fundamental part of the theory, he had to refute it. His continued work along these lines eventually produced the final version of this unified field theory in 1950. The complexity of his development was such that even he questioned the possibility of reducing it to a usable form. The premise underlying the unified field theory is a strong interrelation between mass, gravitation and electromagnetism.

It took Vaclav Hlavaty (of the University of Indiana) to reduce the unified field theory to the point at which some information could be derived from it. Dr. Hlavaty has identified electromagnetic characteristics in both rest-mass and the gravitational field. The electromagnetic field is the basic field. The existence of a gravitational field depends on it's presence.(8)

From this relation, it would seem that the conversion of mass into energy would result in the release of some of the gravitational energy within the mass. The form of this energy release might be gravitons, electromagnetic radiation, or plain gravitational waves.

Dr. Hlavaty believes that gravitation is potentially

controllable. He is continuing the mathematical analysis of Einstein's unified field theory with the idea of making some physical applications of the relationships identified therein. Any results which he has obtained since 1956 have not been reported, however.

The Conference on the Role of Gravitation in Physics held at the University of North Carolina January 18-23, 1957 provided a rich source of information on contemporary theories of gravitation.(15) This assembly of many of the nation's top theoretical physicists is perhaps indicative of the revival of interest in the theory of gravitation.

One of the most interesting of the theories expounded at this conference is that of R. H. Dicke.(12)(16)(17) He questions the validity of the principle of equivalence--which is the basis for the general theory of relativity. According to Dicke, "The gravitational red shift could be expected from elementary considerations of energy conservation involving photons, and hence does not represent a crucial test of General Relativity". Further, he asserts that the deflection of light in the sun's gravitational field, as recently measured, is somewhat larger than that predicted by the equations of the general theory.

The equivalence of inertial and gravitational mass as determined by Eötvös to such accuracy allows Dicke to make some other comparisons. For instance, the ratio of the weight to mass for the electron plus proton is the same as

the neutron with an accuracy of 1 part in 10^7. With an accuracy of 1 part in 10^5, it can be determined that the reduction in mass of the nucleus resulting from the nuclear binding forces is accompanied by a like reduction in weight. With an accuracy of 1 part in 10^5, it can be determined that the electrostatic reduction of the nuclear binding energy is accompanied by a like increase in weight. From these relations, Professor Dicke concludes that the strong interaction constants are approximately position independent. Since the weak interactions do not make much contribution, the accuracy of the Eötvös experiment does not rule out the variation of these interactions with their position. There appears to be something out of the ordinary with these weak interactions which leads Dicke to believe that they may vary with time and position. This is the basis for his development.

Based upon a comparative analysis of the relationships between 1) the ratio which yields the gravitational force between the electron and proton, 2) the age of the universe computed in atomic time, and 3) the square root of the number of heavy particles in the visible part of the universe, it is hypothesized by Dirac(12) that there is a relation between gravitational and atomic quantities, and that, compared with electrical interaction, the gravitational interactions are becoming weaker as time passes. That is to say, the gravitational constant, G, varies in-

versely with the age of the universe. This concept of a variable interaction would lead to a weakening of the principle of equivalence.

In the general theory of relativity, the transformation into Riemannian space-time is used to transform localized gravitational forces into inertial forces. This elimination of local gravitational effects is possible only because of the principle of equivalence. With the possibility that the principle of equivalence may be satisfied only on an approximate basis, Dicke justifies the elimination of the Riemann metric from the Einstein relations. There would no longer be a single universal gravitational acceleration at a given space-time point. This makes possible the introduction of a flat space-metric with gravitational effects then related to a force field.

Dicke mentions several experiments to increase the accuracy of the measurements of gravitational characteristics.(18) Some of these will be discussed in the section on Current Research Efforts.

The possibility of the existence of matter which reacts in a manner opposite to that which is prevalent on the earth (anti-matter) has been considered.(1)(2)(19)(20) The Eötvös experiments supposedly eliminated the possibility of any measurable substances possessing this characteristic. The accuracy of these experiments does not rule out the possibility of some gravitational anomoly, however, due to

the extremely small gravitational effects between masses of less than cosmological magnitude. (The gravitational force required to keep the earth in it's orbit is 2×10^{18} tons; the mutual gravitational attraction of two 180-pound persons standing side by side is a few hundred-thousandths of an ounce.(11))

Morrison and Gold have advanced the theory that it is possible for anti-matter to exist in the universe.(19) They believe that other galaxies could conceivably be made up of this type of matter without it's being evident under present methods of astronomical observation. The only way in which this composition could be noted is in the interaction between anti-matter and matter which results in mutual annihilation and the release of large amounts of energy.

Morrison and Gold note the existence of distant objects in the universe which seem to derive large amounts of energy from presently unexplainable sources. They feel that the possible role of the annihilation process between matter and anti-matter should not be excluded. Since it is possible that anti-matter exists in the universe, they feel that anti-gravitational effects could obtained from it's use in this galaxy's gravitational environment. In contrast to other theorists, (e.g. Bergmann(20)) they also believe that it would be possible to demonstrate the existence of this anti-matter on earth.

The possibility of negative mass is not excluded by

Peter G. Bergmann.(20) He points out that the advantages to be gained from the discovery of such matter are rather dubious from the standpoint of use in a "gravity shield". Even if such matter could exist in it's negative mass state while present on the earth, in order to obtain any appreciable cancellation of the fields of force of the earth's gravitational field, an object comparable in size to that of the earth would be required.

Increasing knowledge of the particle nature of matter yields some interesting phenomena according to Deser and Arnowitt.(10) They believe that the new high-energy nuclear particle family gives rise to new concepts of gravitational energy. These particles are the hyperons and K-particles which have been produced in such high energy accelerators as the Brookhaven Cosmotron and the Berkley Bevatron. In an attempt to fit these particles into their places, Deser and Arnowitt delved into the cosmological theories of Bondi and Hoyle.

The Bondi-Hoyle theory of relativistic cosmology seeks to explain the fact of the expanding universe. (This fact assisted Dirac in framing his hypothesis of a time-dependant gravitational constant.) Deser and Arnowitt believe that the explanation of how the universe can continue it's expansion without a corresponding decrease in the density of matter requires that matter be replenished at the same rate as this expansion.

Deser and Arnowitt submit that this continual creation of matter is linked with the high-energy particles. These particles represent the conversion of gravitational energy into nuclear energy. Under this assumption, they feel that it will be possible to show that the general theory of relativity and the quantum theory can be made to overlap in this one case--that of continuous creation. This conversion also points up the possibility of obtaining usable nuclear energy from gravition.

Deser and Arnowitt feel that the high-energy accelerators will give additional understanding of the links between these high-energy particles and gravitation and eventually bring about the controlled use of gravitational energy.

Certainly, this is not the only theory which has pursued the solution of the unification problem in the subatomic regions. Most of the multi-dimensional theories of gravitation seek to link the electromagnetic field and the gravitational field by some other interrelated field. The submicroscopic domain is about the only place left for this type of a field to exist. There seem to be definite indications for the existence of this third field, for the nuclear binding forces within atomic nuclei are much stronger than either the gravitational or electromagnetic forces. This force which holds the nucleons (protons and neutrons) of the atomic nucleus together is sharply limited to dis-

tances less than about 1.5 Fermis (1 Fermi = 10^{-13}cm), however.(9)

The meson theory which describes the forces within the atomic nucleus results from the work of the Japanese physicist, Yukawa. He theorized that nuclear binding forces are the result of an exchange of particles between nucleons. These particles, called mesons, have been identified.

Yukawa's theory seems to be qualitatively correct, but as yet there has been inadequate experimental verification of it's quantative correctness.

The possibility of the existence of another field with such a small domain is predicted within the multi-dimensional theories of Dr. Bryce S. DeWitt and Professor Burkhard Heim.

Dr. DeWitt envisions a six-dimensional model of the universe.(21) In this six-dimensional space-time continuum, there are five dimensions associated with space and one dimension associated with time. Three of the space dimensions conform to the familiar Cartesian coordinates; the other two are closed upon themselves so as to form a spherical surface. The radius of this spherical surface is extremely small. This makes measurement virtually impossible (which is also the problem with verifying the existence of Yukawa's meson field).

The metric (resulting from the use of curvilinear

coordinates) of this six-dimensional space varies according to equations obtained through the use of a variational principle in much the same manner as was done in Einstein's gravitational relationships. The metric tensor in this relationship describes the gravitational, electromagnetic and meson fields. The fundamental particles are described through the use of a spinor field (a quantum development attributed to Dirac).

Dr. DeWitt's efforts in this line seem promising, but the problem of quantization arises even here. It is necessary that this model universe be mathematically complete, and this is not possible until the troublesome aspects of the quantum theory are either removed or revised to conform to the mathematical structure. The model exists, but the mathematical foundation seems to be far from establishment.

The theory which appears to offer the most promise for application to gravitational control is that of Burkhard Heim, a physicist at the University of Goettingen, Germany.(22) Professor Heim calls his theory the meso-field theory.

The basis for Heim's theory lies in his introduction of a new form of logic which he designates as "syntrometry". He developed this form of logic in an effort to overcome the failings which he feels exist in the present form of mathematical-physical relationships. The seemingly unresolvable differences between the general theory of relativ-

ity and the quantum theory stem from this failure.

By applying syntrometry to mathematical analysis, Professor Heim was able to develop the statements of physical laws in a rather abstract form. By proper manipulation, he is able to arrive at a system of multi-dimensional, nonlinear, partial differential equations which represent a universal natural law of material reality. These equations he calls "meso-field" equations.

Heim was able to establish the truth of this universality by making appropriate approximations in the meso-field equations. He found that in one approximation he obtained the field formulas of the general theory of relativity; in another approximation, relationships analogous to the laws of quantum electrodynamics resulted. With numerous approximations taken throughout the meso-field equations, the extent of all contemporary physical knowledge is obtained. He felt that this gave very good indication of the validity of the meso-field equations.

Other approximations which were made revealed laws other than those which were already a part of physical knowledge. The most significant of these is the indication of a relationship between the gravitational and electromagnetic fields. The major importance of this fact is that Heim believes that he can present experimental confirmation of it. The success of such an experiment would confirm his theoretical approach.

The meso-field equations are defined in a six-dimensional space-time continuum, and relate the gravitational field, the matter field (related to the electromagnetic field), and the meso-field. This relation is accomplished through the use of seven operators which are dependent upon the metrical properties of the space-time continuum. Each of these operators is identified with a particular field. There is one associated with the gravitational field; four with the matter field; and two with the meso-field.

If the meso-field equations are approximated in such a way that the four dimensional space-time continuum results, and the matter fields are restricted to their electromagnetic characteristics, it is determined that there are two states of the meso-field. This indicates that if the meso-field does appear it must do so dually. These states were designated by Heim as the contrabaric state and the dynabaric state. The equations describing these states are operator-equations.

In the contrabaric state, the operator acts on electomagnetic waves to produce a gravitational field, along with gravitational waves.

The dynabaric state describes essentially the same process in reverse. The operator of the dynabaric state acts on the gravitational field to transform it into electromagnetic radiation.

The contrabaric state lends itself to experimental

verification, according to Professor Heim. There are restrictions placed upon the generation of the dynabaric state which require the use of a contrabaric transformer for it's development. Thus, the experimental effort is centered around the construction of a suitable contrabaric transformer.

With the successful construction of the contrabaric transformer and the utilization of the dynabaric state made possible by this development, it becomes possible to accomplish some rather remarkable things.

Upon contrabaric transformation, the energy of the electromagnetic wave becomes a mechanical acceleration. The result of fixing this transformer in a suitable metal (presumably a good conductor) is that it accelerates the electrons in the metal, thereby functioning as a current generator. If the transformer is not held firm, it, and anything to which it is attached, will be accelerated.

With the achievement of the dynabaric state, it will be possible to have a closed system. After the system is initially started, the dynabaric state of the meson field will provide electromagnetic radiation from suitably ionized metal fed continuously into it's field. The electromagnetic radiation can be contrabarically transformed into electric current, which will provide the power needed for the ionization of the metal. As long as the raw material for the ions holds out, this system will continue to oper-

ate. Professor Heim calls this operation dynamic contrabarie.

The excess of energy produced in this system can be utilized by draining it off and using it as desired. Electric power produced in this manner would be one of the usable products of such a system.

If it were desired to use this excess of energy for propulsive purposes, this could be done by channelling the electromagnetic energy into a system of contrabaric transformers arranged so as to act upon an entire vehicular structure. Since the induced field is independent of any external sources, this vehicle would be independent of any surrounding medium. Heim sees no limit on the speed of such a vehicle up to the speed of light. In addition to it's obvious use as an air and space vehicle, he also suggests the possibility of the vehicle's use as a submarine.

The success of Heim's theory would certainly seem to solve many of the problems associated with theoretical physics, today. Although he is a recognized physicist in his own country (1958 Wer ist Wer, the German Who's Who), his theories have not been examined in American professional literature. Part of this difficulty lies in the fact that he does not want to reveal the full character of his meso-field operators until he is able to demonstrate the validity of his theories. He has published some information on his meso-field theories, and there are additional articles

on the applications of dynamic contrabarie which have been published in German.

The latest report (by A. R. Weyl, in February, 1959 (8)) on the status of Professor Heim's work indicates that he has been unable to obtain experimental apparatus of sufficient accuracy to conduct his experiments.

CURRENT RESEARCH EFFORT

The most tangible proposals associated with gravitational research are those associated with the verification of several aspects of the gravitational characteristics. The need for renewed interest in gravitational research has been pointed out by R. H. Dicke.(18) The increased accuracy of the measuring equipment available for this type of research should give much better results than those obtained thirty to forty years ago (the last period of major interest in establishing the accuracy of gravitational characteristics).

Dicke's group at the Palmer Physical Laboratory, Princeton University, has several proposals for checking the validity of some of the theoretical characteristics of gravitation. The first experiment which they have undertaken is an effort to improve the accuracy of the measurements made by Eötvös in 1922 verifying the principle of equivalence.(18) Preliminary results have further substantiated the principle of equivalence to 1 part in 3×10^{11}.

Another project at Palmer is the establishment of a long-term gravimeter to observe the earth's gravitational acceleration over an extended period of time. As a result of these observations, they hope to say something about the

annual variations of the gravitational constant.

Other experiments within this group involve the use of atomic clocks to check on gravitational time and a system to check on the red shift of the spectra of atoms from the sun. There is also some preliminary work being done to increase the accuracy of the measurement of the deflection of light in the sun's gravitational field.

Besides the experimental work being done at the Palmer Laboratory, there are several other experiments being proposed and conducted throughout this country and in Europe.(23)

One of the things predicted by the Einstein general theory of relativity (and still unverified) is the existence of gravitational waves. Many of the recent proposals for experiments are concerned with the generation and detection of gravitational waves.

The proposal by J. Weber involves the use of the earth as a detector for interstellar gravitational radiation.(24) He questions the success of such an endeavor due to the relatively low Q of the earth and the high noise temperature of the core. The other method proposed uses a crystal detector. Incident waves will be detected with the earth as the rotational source for the detection of them. If radiation is incident, it should be noticed in the change of amplifier noise output.

The method of generation of gravitational waves sug-

gested by Mr. Weber requires the use of an electrically driven piezo-electric crystal. The result of driving these crystals just below the breaking point is a radiation of 10^{-13} ergs for each second. This is still substantially undetectable, for the accuracy of measurements suggested above is only about 10^{-3} ergs, and this is quite accurate measurement, comparatively.

Very little of a substantial nature has resulted from recent experiments into the nature of gravitation. The many proposals for experimentation indicate the interest which is now being shown in the desire to answer the many questions pertaining to gravitation. Perhaps some of these experiments will reveal a weakness in the theory of relativity. If so, much of our fundamental physical knowledge will have to be revised.

CONCLUSIONS

It seems virtually impossible to rule out any of the theories which have been proposed. On the other hand, there seems to be very little offered in them for the success of gravitational control within the near future. Continued searching in the depths of the atomic nucleus will undoubtedly reveal more about the fundamental structure of matter. With this revelation may come the insight into the gravitational field which is needed.

The solitary exception to the rather bleak outlook is to be found in Burkhard Heim's work. His theory offers much in all respects. The only problem seems to be his reluctance to discuss the basic portion of his theory. The work which he has been doing for the past five or six years has evidently been unsuccessful in providing the contrabaric conditions which he requires for further exploitation of the meso-field.

The experimental work which is being done in gravitational research also seems to be a minimum. A number of experiments have been proposed, but little information has been published on results, if the proposals have been carried out. Indications are that interest in the experimental aspects of gravitational research is growing, however.

Finally, it appears that there is little encouragement for success in the search for gravitational control. More exact information from the experiments which are proposed may help to eliminate many of the areas of disagreement between the theorists. Then, perhaps, the surviving theories can be interpreted more adequately to give insight into the nature of gravitation.

CHRONOLOGY

Theories and events furthering the knowledge of the nature of gravitation

<u>Ancient theories and concepts</u>:

350 B.C.	Aristotle advanced the concepts of levitation and gravitation.
1564-1642	Galileo demonstrated that the acceleration of gravity is the same for all bodies.
1596-1650	Descarte's vortex theory of gravitation (Ether).
1642-1737	Newton's Law of Universal Gravitation.
1727-1803	LeSage envisioned gravitation as corpuscular in nature.
1831-1879	Maxwell's equations of the electromagnetic field opened up a new mode of physical thinking.
1887	Michelson-Morley experiment dispelled the ether theory.

<u>Modern Theories</u>:

1900	Planck utilized the quantum of action.
1905	Einstein proposed the quantization of the radiation fields (wave-particle duality of the photon).

1905	Einstein's special theory of relativity
1908	Minkowski's concept of the space-time continuum.
1916	Einstein's general theory of relativity.
1924	de Broglie suggested the wave-particle duality of the electron.
1926	Schroedinger and Heisenberg formulated the laws of quantum mechanics.
1927	Dirac proposed the theory of quantum electrodynamics, which accounts for both the wavelike and particle-like properties of radiation.
1920's-1930's	Many experiments seeking to verify Einstein's theories; i.e. deflection of light in gravitational field and gravitational red shift.
1935	Yukawa proposed the basis for the meson field.
1920's-1940's	During this period, several attempts were made to develop a unified field theory.
1950	Einstein's unified field theory: an endeavor to relate both the microscopic and the macroscopic domains.
1950's	Dirac suggests a modification of the ether theory and combination with the quantum theory.

1950's	Hlavaty is successful in reducing part of Einstein's unified field theory to a mathematical form.
1950's	Heim advanced the meso-field theory and proposed to demonstrate his principle of contrabary.
1950's	Many experiments and theories published and discussed.

BIBLIOGRAPHY

1. Aviation Studies (International) Limited. Electro-gravitics Systems. A Report Prepared by Aviation Studies (International) Limited. London, England. February 1956.

2. Aviation Studies (International) Limited. The Gravitics Situation. A Report Prepared by Aviation Studies (International) Limited. London, England. December 1956.

3. Carew, Charles. "The Key to Travel in Space," Canadian Aviation, Vol. 32 (July 1959), pp. 27-32.

4. Intel. "Towards Flight Without Stress, or Strain,--or Weight," Interavia, Vol. 11, No. 5 (May 1956), p. 373.

5. Cleaver, A. V. "'Electro-gravitics': What it is--or Might Be," Aeroplane, Vol. 92, No. 2376 (March 15, 1957), pp. 385-87.

6. Weyl, A. R. "Anti-Gravity," Aeronautics, Vol. 37 (October 1957), pp. 80-86.

7. Cramp, Leonard G. "On the Nature of Gravity," Aeronautics, Vol. 38 (April 1958), pp. 86-93.

8. Weyl, A. R. "Gravity and the Prospects for Astronautics," Aeronautics, Vol. 39 (February 1959), pp. 16-22 (bibliography).

9. Leighton, Robert B. Principles of Modern Physics. New York: McGraw-Hill Book Co., 1959.

10. Deser, S. and Arnowitt, R. The New High-Energy Nuclear Particles and Gravitational Energy. New Boston, N. H.: Gravity Research Foundation, 1954 (essay).

11. Heyl, Paul R. "Gravitation--Still a Mystery," The Scientific Monthly, Vol. 78 (May 1954), pp. 303-306.

12. Dicke, R. H. "Gravitation, an Enigma," American Scientist, Vol. 47, No. 1 (March 1959), pp. 25-40.

13. Schwinger, J. (ed.). Quantum Electrodynamics. New York: Dover Publications, Inc., 1958.

14. DeWitt, Bryce S. "Principle Directions of Current Research Activity in the Theory of Gravitation," Journal of Astronautics, Vol. 4 (Summer 1957), pp. 23-28.

15. ________. "Papers from the Conference on the Role of Gravitation in Physics," Reviews of Modern Physics, Vol. 29, No. 3 (July 1957), pp. 351-546.

16. Dicke, R. H. "Gravitation without a Principle of Equivalence," Reviews of Modern Physics, Vol. 29, No. 3 (July 1957), pp. 363-76.

17. Dicke, R. H. "Principle of Equivalence and the Weak Interactions," Reviews of Modern Physics, Vol. 29, No. 3 (July 1957), pp. 355-62.

18. Dicke, R. H. "New Research of Old Gravitation," Science, Vol. 129, No. 3349 (6 March 1959), pp. 621-24.

19. Morrison, P. and Gold, T. On the Gravitational Interaction of Matter and Antimatter. New Boston, N. H.: Gravity Research Foundation, 1957 (essay).

20. Bergmann, Peter G. "Gravity Shields," Science, Vol. 125 (15 March 1957), p. 498.

21. DeWitt, Bryce S. New Directions for Research in the Theory of Gravitation. New Boston, N. H.: Gravity Research Foundation, 1953 (essay).

22. Heim, Burkhard. A Report on the Development of the Principle of Dynamic Contrabarie. New Boston, N. H.: Gravity Research Foundation, 1956 (unpublished essay).

23. Stearns, H. O. Gravitation. New Boston, N. H.: Gravity Research Foundation, 1960 (pamphlet).

24. Weber, J. Gravitational Waves. New Boston, N. H.: Gravity Research Foundation, 1959 (essay).

25. Gerardin, L. A. A. "Electro-gravitic Propulsion," Interavia, Vol. 11, No. 12 (December 1956), p. 992.

26. Abel, R. Cox. "Levitation," Aeronautics, Vol. 35 (September 1956), pp. 68-72.

27. Kit, B. and Zavistovich, R. R. "What is Graviation?..

Some Soviet Views," Air Force, Vol. 42, No. 2 (February 1960), pp. 64-67.

28. Belinfante, F. J. On the Possibility of Disco Reflectors or Absorbers of Gravity and of Cons ing Effective Sources of Gravitational Waves. Boston, N. H.: Gravity Research Foundation, 19 (essay).

29. Cocconi, G. and Salpeter, E. A Search for Anis phy of Interia. New Boston, N. H.: Gravity Re Foundation, 1958 (essay).

30. Bergmann, Peter G. Introduction to the Theory Relativity. Englewood Cliffs, N. J.: Prentice Inc., 1942.

31. _______. "Relativity and Gravitation on the Anti-gravity," Aero/Space Engineering, Vol. 18 (December 1959), p. 23 (abstract).

32. Peaslee, D. C. "Nonexistence of Gravity Shiel Science, Vol. 124 (28 December 1956), p. 1292.

33. Einstein, A. The Meaning of Relativity. Princ N. J.: Princeton University Press, 1945.

34. Møller, C. The Theory of Relativity. London: University Press, 1957.